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The number of patients simultaneously present at the emergency department as an indicator of unsafe waiting times: A receiver operated curve-based evaluation

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ABSTRACT

Background: Emergency department (ED) crowding and prolonged waiting times have been associated with adverse consequences towards quality and patient safety.
Objective: This study investigates whether the number of patients simultaneously present at the ED might be an indicator of unsafe waiting and at what threshold hospital-wide measures to improve patient outflow could be justified.
Methods: Data were retrospectively collected during a 1-year period; all ED patients aged ⩾16 years, and triaged as ESI-1 or ESI-2 were eligible for inclusion. The number of patients simultaneously present was used as occupancy rate. Waiting time was considered unsafe if it was longer than 10 min for ESI-1 patients, or longer than 30 min for ESI-2 patients. Differences in waiting time and occupancy between patients with safe and unsafe waiting times were analysed using the Mann–Whitney *U* test. The ability of the occupancy rate to discriminate unsafe waiting times was analysed using a receiver operating characteristic curve.
Results: The overall median waiting time was 5 min (IQR = 4–8) for ESI-1, and 12 min (IQR = 6–24) for ESI-2 patients. Unsafe waiting times occurred in 16.0% of ESI-1 patients (median waiting time = 17 min, IQR = 13–23), and in 18.9% of ESI-2 patients (median waiting time = 48 min, IQR = 37–68). The occupancy rate was a weak indicator for unsafe waiting times in ESI-1 patients (AUC = 0.625, 95%CI 0.537–0.713) but a fair indicator for unsafe waiting times in ESI-2 patients (AUC = 0.740, 95%CI 0.727–0.753) for which the threshold to predict unsafe waiting times with 90% sensitivity was 51 patients.
Conclusion: The number of patients simultaneously present is a moderate indicator of unsafe waiting times. Future initiatives to improve safe waiting times should not focus solely on occupancy, and expand their focus towards other factors affecting waiting time.

Introduction

Over the last years, there has been sufficient evidence of the increasing problem of emergency department (ED) crowding worldwide. Numerous studies have demonstrated the adverse consequences associated with crowding, and a growing number of government and professional reports express the need to solve the "ED crowding problem" (McClelland et al., 2011; Pines et al., 2011). It is generally recognised that factors associated with patient flow should be held responsible as the root cause of the problem. More specific, the difficulty in transferring ED patients to a hospital bed are seen as the most important factors (Pines et al., 2011).

As long as hospitals, and by extension the entire healthcare system, are unable to provide suitable solutions, emergency departments (EDs) will be faced with the consequences of crowding. These consequences include prolonged waiting times, a decreased quality of care, and an increased risk of adverse events (Hoot and

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Aronsky, 2008). In an attempt to cope with the associated risks of prolonged waiting times, EDs have implemented triage systems. The main objective of a triage system is to rapidly identify the most vulnerable patients, those who cannot wait to be seen, and provide these patients priority access to the diagnostic–therapeutic process (Gilboy et al., 2011). Therefore triage systems suggest target times for physician evaluation in high urgency situations. Although there are differences between the systems, they all agree that high urgency patients should have quick, if not immediate, access to appropriate care and treatment.

Currently EDs are increasingly unable to guarantee safe waiting times for high urgency patients (Triggle, 2013). In an attempt to reduce the potential adverse consequences associated with these unsafe waiting times, a taskforce was set up in our hospital. This team consisted of clinical staff, management executives and (external) patient safety experts. The objective of this team was to analyse the current situation and identify potential, hospital-wide, measures to improve the outflow of ED patients. The launch of hospital-wide measures requires a certain indicator of when action should be taken. Prior to this study, the criterion to indicate ED crowding was set at 65 patients simultaneously present in the ED. It was, however, not clear on what basis this value was established.

The objective of this study was twofold. On the one hand this paper investigates whether the number of patients simultaneously present at the ED might be an indicator of unsafe waiting times. As a second objective, it considers at what threshold hospital-wide measures to improve patient outflow could be justified.

Methods

Design and setting

This retrospective observational study was part of a larger quality improvement program at the ED of a tertiary referral academic teaching hospital in Belgium. The ED has an annual census of approximately 55,000 patients with an average hospital admission rate of 36%. The latter is in accordance with the average national rate. Overall, the median length of ED stay is 217 min. The ED consists of an admission and treatment area with 16 cubicles, including 3 resuscitation cubicles and 4 separate cubicles for minor trauma patients. There is a dedicated space with 4 cubicles for paediatric patients, which is staffed with a doctor and a nurse trained in paediatrics. In addition, the ED contains a 25-bed observation ward, of which 7 beds are equipped for intensive care and serve as a waiting zone in times of intensive care unit (ICU) bed shortage. Since January 2009, the 5-level Emergency Severity Index (ESI) is used to determine the treatment urgency and priority of patients visiting the ED (Wuerz et al., 2000). The ESI seeks to accomplish two main goals: patient sorting and patient streaming (Gilboy et al., 2011). As such, the ESI aims to accomplish these goals by (1) determining which patient should be seen first and (2), what resources are required to determine the patients' disposition. The most urgent level, ESI-1, is assigned in case immediate life-saving interventions are required, which are clearly defined in the ESI manual (Gilboy et al., 2011). Patients presenting with high-risk conditions or severe pain/distress are assigned to ESI-2. Although examples are provided, the interpretation of the criteria is based on triage nurses knowledge and experience. The following three levels of the ESI are assigned based on the estimated number of resources that a patient needs to reach a dispositional decision.

Recruitment

All ED patients, aged ⩾16 years and triaged as ESI level-1 or level-2 during a 1-year study period from January 2012 to December 2012, were eligible for inclusion in the study. Patients presenting with mental health problems were excluded, because their care was provided in a separate area with dedicated staff.

Variables and definitions

The number of patients simultaneously present at the ED was used as occupancy rate. The number of patients present at the ED is recorded every 10 min by the hospital's computer system. For each included patient, the occupancy rate was calculated as the mean number of patients present at the ED during the first hour of attendance, starting from the time of registration.

Waiting time was defined as the time (minutes) between registration of the patient in the ED information system and placement in a treatment cubicle. The later is registered by a care provider in the information system.

To define unsafe waiting times maximum waiting times for ESI-level 1 and ESI-level 2 patients were set. While the ESI does not indicate specific time intervals to physician evaluation, it suggests the following for ESI-level 1 patients "*ESI level-1 patients are seen immediately because timeliness of interventions can affect morbidity and mortality*" (Gilboy et al., 2011) and for ESI-level 2 patients "*All level-2 patients are still potentially very ill and require rapid initiation of care and evaluation. The triage nurse has determined that it is unsafe for these patients to wait. Patients currently may be stable, but may have a condition that can easily deteriorate; initiation of diagnostic treatment may be time sensitive (stable chest pain requires an ECG within 10 minutes of arrival); or the patient may have a potential major life or organ threat. ESI level-2 patients are still considered to be very high risk*" (Gilboy et al., 2011). Based on a pragmatic interpretation of these recommendations, unsafe waiting times were defined as follows: for ESI-level 1 patients a maximum of 10 min waiting time and for ESI-level 2 patients a maximum waiting time of 30 min. The other ESI categories were not taken into consideration, as from a clinical standpoint these patients are considered stable and can wait several hours before being seen by a physician or care provider.

Data collection

Data was collected from the hospital information system (clinical work station – University Hospitals Leuven). This system allows the extraction of detailed process times on patient level. First, all eligible patients were selected and variables regarding triage, waiting time and time of registration were obtained. A second dataset, containing the number of patients simultaneously present, was used to calculate the occupancy rate at each patient's registration time. Finally, all variables were aggregated into the research database.

Statistical analysis

The obtained data was descriptively analysed using numbers and percentages for categorical variables and the median and interquartile range (IQR) for continuous variables. Differences in waiting time and the number of patients simultaneously present for patients with safe and unsafe waiting times were analysed using the Mann–Whitney *U* test. The ability of the occupancy rate (number of patients simultaneously present at the ED) to discriminate unsafe waiting times was analysed using a receiver operating characteristic (ROC) curve. The ROC curve plots sensitivity against (1 − specificity) for all possible thresholds in a binary classification task. The area under a ROC curve (AUC) represents the overall discriminatory ability of a test, where a value of 1.0 denotes perfect ability and a value of 0.5 denotes no ability.

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When a diagnostic test is based on a continuous variable, the ROC curve describes the performance of a model across the entire range of classification thresholds. A range of different decision thresholds or cut-off values may be investigated in order to identify the most preferable one. Sensitivity and specificity have been calculated for each of the cut-off values. It is desirable to choose a cut-off value that has high values for both sensitivity and specificity. In practice, the sensitivity and specificity may not be regarded as equally important. For example, a false-negative finding may be more critical than a false-positive one, in which case a cut-off with a relatively high specificity would be preferable. However, if there is no judgement on the preference between the two, then Youden's index (J) may be used to choose an appropriate cut-off: J = sensitivity + specificity − 1. In a perfect test, the value J achieves a maximum of 1; the value J equals 0 when the test has no diagnostic value.

All P values were two-sided, and statistical significance was set at a P value of less than 0.05. All analyses were performed with the R statistical software package (version 2.15.1).

Ethical considerations

Given the retrospective design, this study was not subjected to an ethical advisory board. The data used in this study was obtained from a database used for business information appliances. This database is in compliance with the national law on the protection of privacy.

Results

Of the 54,280 patients who visited the ED during the study period, 44,389 patients were older than 16 years of age. A total of 9458 patients (21.3%) were triaged as ESI level-1 or ESI level-2 and therefore included in the study. Of these, 344 patients (3.6%) were assigned as ESI level-1, and 9114 patients (96.4%) as ESI level-2. Complete data was available in 99.1% of study patients (n = 9369). Patients with incomplete data were excluded for further analysis.

The overall median waiting time for ESI level-1 and level-2 patients was 5 min (IQR = 4–8) and 12 min (IQR = 6–24), respectively. Unsafe waiting time occurred in 16.0% of ESI level-1 patients with a median waiting time of 17 min (IQR = 13–23), and in 18.9% of ESI level-2 patients with a median waiting time of 48 min (IQR = 37–68). A summary of these waiting times is presented in Table 1.

Number of patients simultaneously present at the ED as an indicator for unsafe waiting times

The number of patients simultaneously present differed significantly between ESI level-1 patients with a safe waiting time (median = 54, IQR = 47–66) and those with a unsafe waiting time (median = 64, IQR = 50–75), P = 0.003. Likewise, for ESI level-2 patients the number of patients simultaneously present differed significantly between patients with safe waiting times (median = 55, IQR = 45–65) and those with unsafe waiting times (median = 67, IQR = 59–75), P < 0.001.

ROC analysis for the number of patients simultaneously present in detection of unsafe waiting times for ESI level-1 patients provided an AUC of 0.625 (95% confidence interval (CI) 0.537–0.713; P = 0.003) (Fig. 1). The AUC for detecting unsafe waiting times for ESI level-2 patients was 0.740 (95%CI 0.727–0.753; P = 0.000) (Fig. 2).

Threshold for initiation of hospital-wide measures

Based on the Youden's index, the best cut-off value for detecting unsafe waiting times was equal to or higher than 60 patients simultaneously present at the ED. With regard to the detection of unsafe waiting times, this threshold resulted in a sensitivity of 0.618 and a specificity of 0.657 for ESI level-1 patients, while for ESI level-2 patients the sensitivity and specificity were respectively 0.738 and 0.627. In order to achieve 90% sensitivity in detecting unsafe waiting times, the threshold for the number of patients simultaneously present at the ED was 36 for ESI level-1 patients (0.093 specificity), and 51 for ESI level-2 patients (0.418 specificity).

Discussion

This observational study, performed in one tertiary referral centre, used the occurrence of unsafe waiting times for ESI level-1 and level-2 patients as a proxy for the adverse consequences associated with ED crowding. An occupancy measure, based on the number of patients simultaneously present at the ED, was used to determine at what point unsafe waiting times occurred. This indicator was found to be a weak predictor for unsafe waiting times in ESI level-1 patients (AUC = 0.625; 95%CI 0.537–0.713), but a fair indicator for unsafe waiting times in ESI level-2 patients (AUC = 0.740; 95%CI 0.727–0.753).

Sixteen per cent of ESI level-1 patients had a waiting time of more than 10 min (median 17 min), although one can argue whether these waiting times are a problem in the first place. Clinical staff, present during taskforce meetings, confirmed that they were not worried about the waiting times for ESI level-1 patients, for which two reasons were mentioned. First, these patients are generally placed in a resuscitation room prior to registration in the ED information system. Second, in cases where ESI level-1 patients had to wait for an available resuscitation room, they are never left unattended. In other words, the measured waiting times for ESI level-1 patients does not always clearly represent the real life situation. Given the high urgency (often resuscitation) of ESI level-1 patients, it seemed logical that staff's priority was to stabilise the patient to the expense of obtaining administrative data. In contrast, a total of 18.9% of ESI level-2 patients had a waiting time of more than 30 min (median 48 min). Given the poor clinical condition of these patients, the occurrence of such unsafe waiting times should be prevented. Best cut-off value for detecting unsafe waiting times based on the Youden's index was set at 60 patients simultaneously present at the ED. In order to achieve 90% sensitivity, the threshold must to be set at 51 patients simultaneously present at the ED (0.418 specificity).

The emergence of unsafe waiting times stems from several factors within three interdependent components: input, throughput,

Table 1
Summary of waiting times.

	Overall waiting time (min)		Safe waiting time (min)			Unsafe waiting time (min)		
	Median	IQR	%	Median	IQR	%	Median	IQR
ESI level-1	5	4–8	84.0	5	3–7	16.0	17	13–23
ESI level-2	12	6–24	81.1	9	5–16	18.9	48	37–68

min = minutes; IQR = interquartile range; ESI = Emergency Severity Index.

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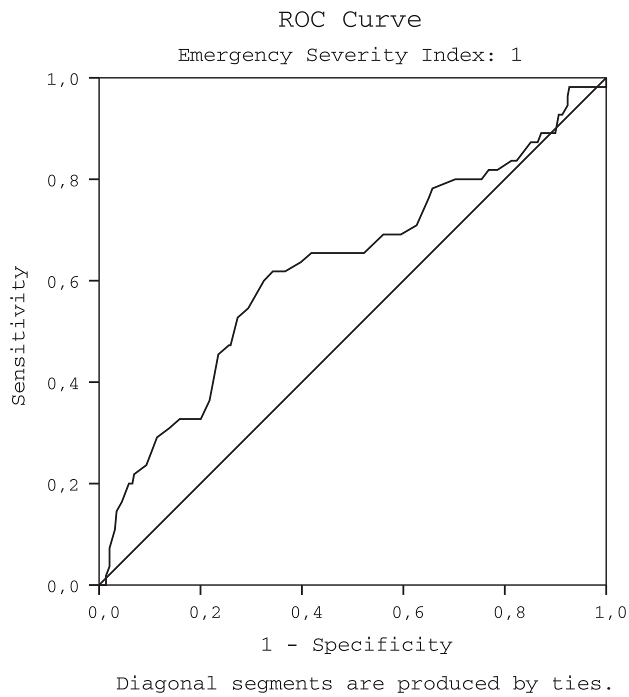

Fig. 1. ROC curve showing the predictive power for the number of patients simultaneously present in the ED on the occurrence of unsafe waiting times in ESI-level 1 patients.

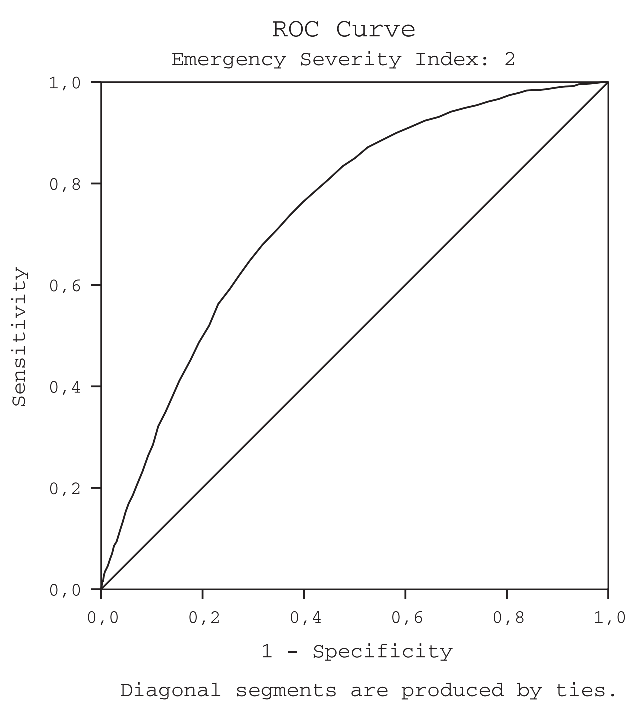

Fig. 2. ROC curve showing the predictive power for the number of patients simultaneously present in the ED on the occurrence of unsafe waiting times in ESI-level 2 patients.

and output (Asplin et al., 2003; Hoot and Aronsky, 2008). Since the recognition of the ED crowding problem, most attention has been drawn to the number of patients present at the ED. Following Asplin's model of ED crowding, this number results from a combination of input and output factors (Asplin et al., 2003). As this study shows, the number of patients simultaneously present is itself a moderate indicator of unsafe waiting times for high urgency patients. It can, therefore, only be held partially responsible for the occurrence of unsafe waiting times. This suggests that throughput factors play an important part in the manifestation of unsafe waiting times. Throughput is affected by patient characteristics (e.g. the level of care a patient requires), organisational factors (e.g. availability of treatment spaces, staffing levels, organisation of care) and the resilience or the positive ability of ED staff to adapt to the consequences of the excessive number of patients present at the ED. In order to improve safe waiting times future initiatives need to consider these additional causal factors. In other contexts the knowledge and experience of nurses and physicians alike have been associated with improved outcome. It is therefore not inconceivable that these factors also apply to crowding. Competent medical and nursing staff, communication, teamwork, clinical leadership and cultural change are some examples which can improve the resilience of EDs and hospitals to deal with the causative factors of ED crowding.

The second objective of this study was to set a threshold for the number of patients simultaneously present at the ED to indicate unsafe conditions. This study suggests that the threshold value should be set at 51 patients. This value is close to the 59 beds in the studied ED (cubicles, observation ward and overflow locations). This might suggest that the occupancy level, as suggested by Hoot and colleagues, can be a meaningful measure for real time crowding prediction (Hoot et al., 2007). The study by Hoot and colleagues investigated the potential for monitoring current and near-future ED crowding by using 4 measures: the Emergency Department Work Index (EDWIN), the National Emergency Department Overcrowding Scale (NEDOCS), the Demand Value of the Real-time Emergency Analysis of Demand Indicators (READI), and the Work Score. The ED occupancy level was used as a control measure for baseline comparison. The occupancy level was calculated using the following formula: $100 * P_{bed}/B_t$. Where P_{bed} = number of patients in licensed beds and overflow locations, such as hallway beds or chairs; and B_t = number of licensed treatment beds. They found the occupancy level having highest discriminatory power. None of the measures provided substantial advance warning before crowding at low rates of false alarms.

Limitations

The findings of this study are subject to several limitations. First, the study was performed in only one Belgian tertiary referral university hospital. As a result, findings cannot be generalized to other EDs or countries. However, the suggested method could be of interest for many EDs. Second, given the retrospective design of the study, data were based on historical figures. The variables used in our analysis are prone to changes due to alternations in workflow, architectural design, etc. Therefore, it is important to evaluate the threshold values at regular times, and especially after the implementation of interventions aimed to reduce waiting times. Third, given the retrospective design it was difficult to pinpoint the exact time a patient had to wait before being evaluated and treated. The time to placement in a treatment cubicle was seen as the most accurate and available indicator of the actual waiting time. We do recognise however that some patients already received evaluation and even treatment before placement in a treatment room. Last, the assessment of patient safety is a huge challenge. Measuring patient harm resulting from healthcare management is much more difficult as compared to the evaluation of clinical quality outcomes (Vincent et al., 2013). First, not all harm is immediately visible in the ED as patients could be transferred to a hospital ward or discharged to their homes. Second, some adverse events could be resolved within the ED and could therefore not be detected using retrospective data. Third, there are relatively

few ways in which things can go right but innumerable ways in which things can go wrong. In other words, patients can be harmed in many different ways. As such, this study attempted to measure a universe of possibilities that could only be partially specified in advance. Therefore, we did not predefine unsafe waiting on the basis of damage incurred. Instead, we pragmatically defined unsafe waiting times as the point at which quality of care would potentially decrease and adverse events due to treatment delay could occur. This interpretation is in line with current understandings of unsafe conditions (Aven, 2013; Hollnagel, 2013).

Conclusion

In conclusion, this study shows that the number of patients simultaneously present at the ED is a moderate indicator of unsafe waiting times for ESI level-2 patients. In our ED, we set the threshold to 51 patients simultaneously present to predict unsafe waiting times with a sensitivity of 90%. The results of this study suggest that in order to improve safe waiting times the focus towards the number of patients present at the ED should be expanded to include other causal factors of unsafe waiting times. Improving organisational resilience by strengthening the ability to adapt to the consequences of the excessive number of patients present at the ED seems a meaningful proposition.

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Author contributions

Conception and design: J. Bergs, S. Verelst. Acquisition of data: S. Vandoren. Analysis and interpretation of the data: J. Bergs, S. Verelst, D. Vandijck. Drafting of the article: J. Bergs, S. Verelst, D. Vandijck. Critical revision of the article for important intellectual content: J.-B. Gillet, P. Deboutte, S. Vandoren. Final approval of the article: J. Bergs, S. Verelst, J.-B. Gillet, P. Deboutte, S. Vandoren, D. Vandijck. Statistical expertise: J. Bergs. Administrative, technical, or logistic support: P. Deboutte.

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